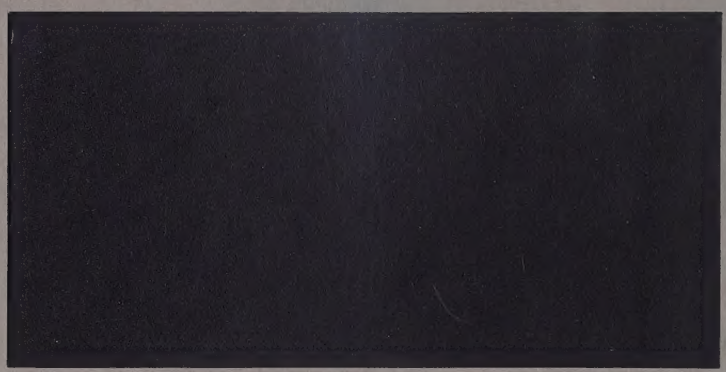
INSTRUCTION MANUAL

REGATRON
PRECISION CALIBRATED
POWER SUPPLY

MODEL 2603AK

SERIAL NO. _____

ELECTRONIC
MEASUREMENTS
COMPANY, INCORPORATED
EATONTOWN NEW JERSEY



PRELIMINARY INSTRUCTION MANUAL

REGATRON
PRECISION CALIBRATED
POWER SUPPLY

MODEL 2603AK

SERIAL NO. _____

ELECTRONIC MEASUREMENTS COMPANY INC.
EATONTOWN, NEW JERSEY

C462

WARRANTY

This instrument is guaranteed to be free from defects in material and workmanship for one year from the date of purchase (except for tubes, fuses, and pilot lamps). Our liability under this warranty is limited to repairs and adjustments or replacements of defective parts or instruments when the fault is a direct result of defective materials or workmanship in the manufacture of the apparatus. This warranty covers service for the first year, except for transportation to and from the factory.

If, during subsequent service, any fault develops in the equipment, the following steps should be taken:

1. Notify ELECTRONIC MEASUREMENTS CO. INC., giving full particulars of the difficulty and include the serial number of the instrument in question. On receipt of this information, we will give you service information or shipping instructions.

2. On receipt of shipping instructions, forward the apparatus to us, prepaid, and we will make repairs and adjustments immediately at the factory.

3. If the fault has been caused by misuse, or abnormal conditions of operation, as disclosed by our examination, repairs will be billed at cost. In this case, an estimate of the cost will be submitted before work is started.

ELECTRICAL STANDARDS

All company primary standards are either certified directly or are traceable to certification by the National Bureau of Standards.

CLAIM FOR DAMAGE IN SHIPMENT

This instrument received comprehensive visual and electrical inspections before shipment. Immediately upon receipt from the carrier and before operation, this instrument should be inspected visually for damage caused in shipment. If such inspection reveals internal or external damage in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. When referring to this instrument, always include the model and serial numbers.

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C462

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TABLE OF CONTENTS

	Page
SECTION 1. DESCRIPTION	
Figure 1-1. Precision Calibrated Power Supply	1
1-1. GENERAL	1
1-2. APPLICATION	1
1-3. TABLE OF SPECIFICATIONS	2
SECTION 2. OPERATION	
2-1. INSPECTION	3
2-2. INSTALLATION	3
2-3. CONTROLS AND FUSES	3
2-4. INITIAL CONTROL SETTINGS	4
2-5. OPERATION	4
SECTION 3. CIRCUIT DESCRIPTION	
3-1. GENERAL	5
3-2. BLOCK DIAGRAM	5
Figure 3-1. Block diagram	5
3-3. POSITIVE SUPPLY	5
3-4. NEGATIVE SUPPLY	6
3-5. COMPARATOR	6
Figure 3-2. Comparator configuration	6
3-6. BALANCED INPUT DETECTOR	6
3-7. ERROR AMPLIFIER	7
3-8. SERIES TUBES	7
3-9. CHOPPER STABILIZER	7
3-10. OUTPUT CIRCUITRY	7
3-11. DECADE SYSTEM	7
SECTION 4. MAINTENANCE	
4-1. GENERAL	8
4-2. NULL ADJUSTMENT	8
4-3. NULL ADJUSTMENT FOR CHOPPER-STABILIZED UNITS	8
4-4. CALIBRATION OF OUTPUT VOLTAGE	8
4-5. CALIBRATION OF OUTPUT CURRENT MILLIAMMETER	9
4-6. GENERAL FAULTS	9
4-7. PARTS REPLACEMENT	10
4-8. CLEANING AND LUBRICATION	10
4-9. TROUBLE SHOOTING	10
4-10. VOLTAGE AND RESISTANCE MEASUREMENTS	12
SECTION 5. PARTS LIST AND SCHEMATIC DIAGRAM	

Figure 1-1. Precision Calibrated Power Supply.

SECTION I

DESCRIPTION

1-1. GENERAL. This Precision Calibrated Power Supply (Figure 1-1) has been developed to meet the need for an accurate, calibrated source of dc voltage with high current capabilities.

All operating controls and indicators are located on the front panel of the power supply. A three-section Decade makes it possible to select any output voltage between zero and 300 volts, in one-, ten-, and hundred-volt steps. A Vernier, covering a continuous range from zero to one volt, is used to obtain any voltage between the one-volt steps. Output can be taken from front panel universal binding posts.

A direct-reading milliammeter is provided for monitoring the output current. This meter is also used with a front panel screwdriver adjust control to make possible a null-balance check at any time, even while the power supply is in use. An additional screwdriver adjust control is available at the front panel for calibration of the instrument. This eliminates the necessity for removing covers, etc., when making periodic checks and adjustments.

1-2. APPLICATION. This instrument is capable of serving a wide variety of laboratory, production, and system applications in which a calibrated dc voltage source of high accuracy is a requisite. It can, for instance, be used to calibrate meters and power supplies; for precise measurement of electron tube parameters; as an external reference source for power supplies; as an extremely stable voltage source for high gain dc amplifiers; and as a voltage standard for bridge, network, and differential measurements.

1-3. TABLE OF SPECIFICATIONS.

Output Voltage	0-300volts dc.
Output Current	Model 2601, 0-100 milliamperes. Model 2602, 0-200 milliamperes. Model 2603, 0-300 milliamperes.
Accuracy of Voltage Setting	Settings accurate within 0.1% or 25 millivolts*. 1-volt Vernier has overall tolerance of ±5% corresponding to 50 millivolts.
Regulation	Less than 0.03% or 30 millivolts* for line variations from 105 to 125 volts. Less than 0.02% or 20 millivolts* from zero to full load.
Regulation With Chopper Stabilization	0.01% or 3 millivolts* for line or load variations.
Stability	Output remains within 0.1% or 20 millivolts* of setting for 8 hours after 30-minute warmup under fixed line, load, and temperature conditions.
Stability With Chopper	0.05% +2 millivolts, same condition as above.
Ripple and Noise	Less than 1 millivolt rms at any load within rating.
Output Impedance	0.01 ohm up to 1000 cycles. Less than 0.1 ohm up to 10 kc. Less than 2 ohms up to 100 kc.
Regulation Speed	Less than 0.2 milliseconds.
Overload Protection	Line and high voltage supply fused.
Primary Input	105-125 volts, 50-60 cps, single-phase power.
Terminations	Front: universal binding posts. Rear: barrier-type terminal strips (optional).
Mounting	Table or rack mounting.
Dimensions	7 inches high, 15 inches wide, 11 inches deep.
Weight	33 pounds, approximately.
Finish	Gray enamel with black silk screened designations.

*Whichever is greater.

SECTION 2

OPERATION

2-1. INSPECTION. Prior to placing the Precision Calibrated Power Supply in operation, inspect the interior and check to see that all tubes are securely seated in their sockets. Damage incurred during shipment should be handled in accordance with the instructions on the Warranty page, to be found opposite the Table of Contents page at the front of this instruction manual.

2-2. INSTALLATION. This power supply operates on 105-125 volts, 50-60 cps, single-phase power. It may be rack-mounted or used on a table. Sufficient clearance should be provided above and below the power supply to maintain the ambient temperature within the specified limits. The top and bottom covers may be removed to increase ventilation.

2-3. CONTROLS AND FUSES. The following controls and fuses are located on the front panel of the power supply (see Figure 1-1):

CONTROL OR FUSE	FUNCTION
LINE switch	Controls application of ac power input to power supply.
LINE fuse	5A fuse protects primary input circuit against overload.
CAL screwdriver adjust control	Adjusts output voltage to comply with Decade and Vernier control settings. (Refer to paragraph 4-4).
NULL screwdriver adjust control	Adjusts balanced input detector to null or zero level. (Refer to paragraph 4-2.)
H.V. fuse	3/8A fuse protects output circuit against overload.
H.V. switch	Controls application of output voltage.
Meter switch	Permits front panel milliammeter to monitor output current or to check null balance.
Decade	Selects output voltage between zero and 300 volts in 1-, 10-, and 100-volt steps.
Vernier	Provides additional zero to one volt adjustment of decade selected output voltage.

2-4. INITIAL CONTROL SETTINGS. Adjust the controls on the front panel to the positions indicated below:

CONTROL	POSITION
LINE switch	Off (down)
H. V. switch	Off (down)
Meter switch	OFF (center)
Decade	Minimum voltage (fully counterclockwise)
Vernier	Minimum voltage (fully counterclockwise)

2-5. OPERATION. Proceed as follows to place the power supply in operation:

a. Connect a link between the GND binding post and either the + or - binding post.

b. Plug the power supply into an appropriate ac power source. Refer to the Table of Specifications, paragraph 1-3, for the primary input requirements.

c. Throw the LINE switch to the on (up) position.

d. Connect a load between the + and - binding posts.

e. Set the Decade and Vernier to obtain the desired output voltage. To read the output voltage, add the voltages indicated by all the dials; thus, settings of 100, 50, 3, and .6 would mean 153.6 volts.

f. Wait one minute then throw the H. V. switch to the on (up) position. Output voltage is now applied to the load.

g. Throw the Meter switch to the LOAD CURRENT (up) position and read the front panel milliammeter to monitor the output current.

SECTION 3

CIRCUIT DESCRIPTION

3-1. GENERAL. This section describes the circuitry used in the Precision Calibrated Power Supply. The following discussions relate directly to the schematic diagrams in Section 5 of this instruction manual.

3-2. BLOCK DIAGRAM. Basically, the power supply can be divided into 5 circuit groups, all of which are interconnected as shown in Figure 3-1. Should a disturbance occur which affects the output voltage, a disturbance either in the ac line input or in the characteristics of the load connected to the power supply, the comparator will produce an unbalance which will be sensed by the balanced input detector. The result is an error signal from the detector. This error signal is brought to a usable level by the error amplifier, and then applied as a bias correction to the series amplifiers. As a result, the conduction of the series amplifiers is readjusted and the output voltage is brought back to its original value. This in turn reduces the output of the comparator toward zero, so that the system returns to equilibrium.

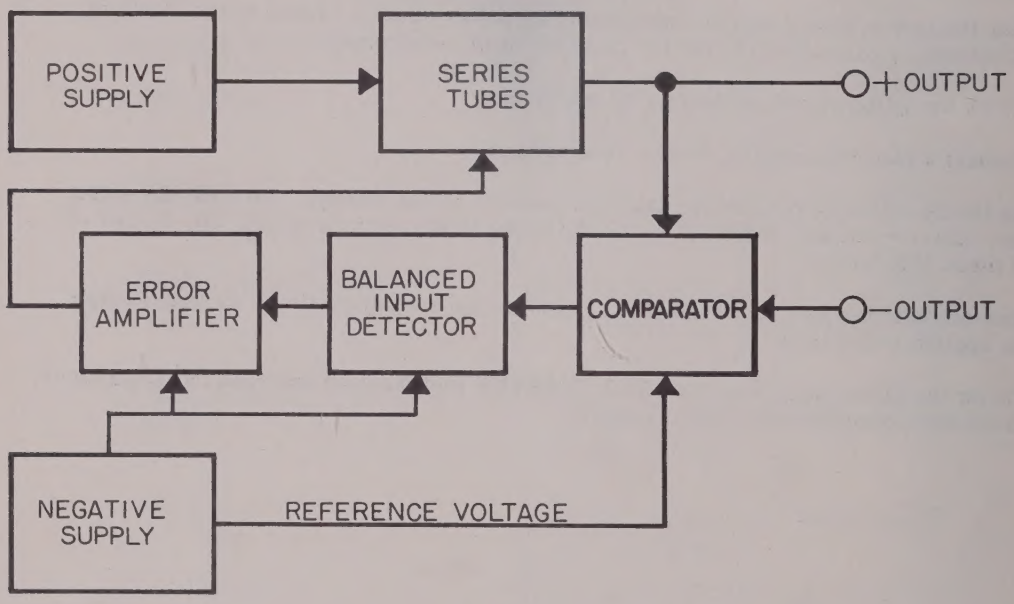


Figure 3-1. Block diagram.

3-3. POSITIVE SUPPLY. Transformer T1 supplies high voltage to all the rectifiers, and filament voltage for all the tubes in the power supply. The output of full wave rectifiers V1 and V2 is applied directly to the plates of series tubes V12 through V16. Capacitors C1 and C2 serve as a filter. The rectified and filtered output voltage is also applied through a voltage divider to VR tubes V3 and V4, so that a regulated stepped-down voltage is obtained for the plates of balanced input detector V11. Screen grid voltage for the series tubes is supplied by silicon rectifiers CR1 through CR4 in full wave bridge rectification, with filtering provided by capacitor C3. This supply also provides initial plate voltage for error amplifier V8, and control grid bias for the series tubes.

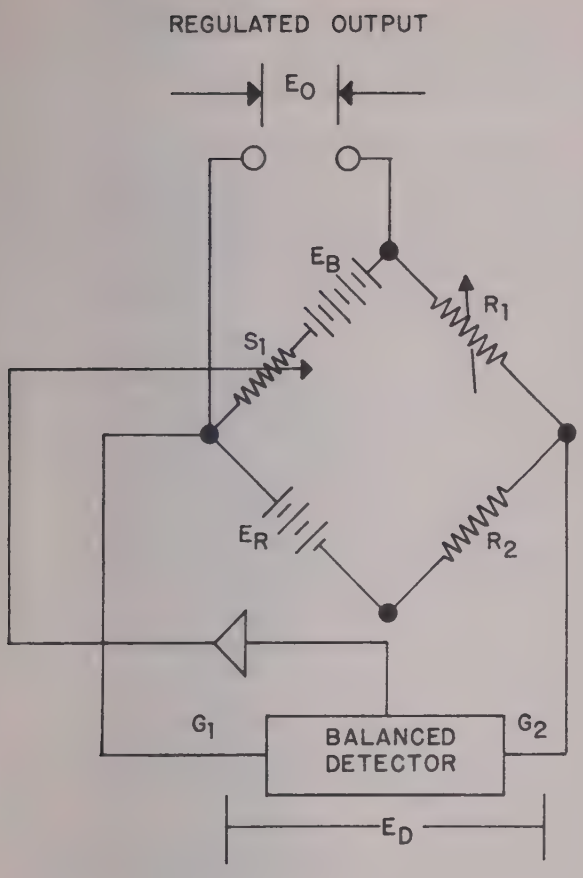


Figure 3-2. Comparator configuration.

3-4. NEGATIVE SUPPLY. The negative supply uses silicon rectifiers CR5 through CR7 in half wave rectification. The output of the rectifiers is filtered by an RC network consisting of capacitors C4 and C5 and resistor R5, dropped to the appropriate potential by resistor R6, and preregulated at -150 volts by VR tube V5. The negative potential is then dropped to -108 volts by resistor R7, further regulated by VR tube V6, dropped again by resistor R8, stabilized at -85 volts by VR tube V7, and finally dropped to -43 volts by voltage divider resistors R9 and R10. The regulated -108 volts is employed at the cathode of balanced input detector V11 and the control grid of error amplifier V8. The regulated -85 volts is the reference potential for the comparator and is also employed at the cathode of the error amplifier. The -43 volts is applied to the screen grid of the error amplifier.

Diode CR8 functions as a one-way switch. This diode disconnects VR tube V6 from the junction of resistors R7 and R8 to permit momentary application of the VR tube high-firing potential through resistor R4. As soon as the VR tube has fired, the diode closes the path from the junction of the two resistors, thus permitting normal current flow through the VR tube and clamping the momentary firing potential.

3-5. COMPARATOR. Figure 3-2 illustrates the comparator configuration in simplified form. If inputs G_1 and G_2 are equal ($E_D = 0$) then:

$$\frac{E_O}{E_R} = \frac{R_1}{R_2} \text{ and } E_O = E_R \times \frac{R_1}{R_2}$$

where E_O = regulated output voltage
E_R = internal reference voltage
and R_2 is a fixed resistor.

Since E_R and R_2 are constant, $E_O = KR_1$; or, the output voltage is dependent only upon the value of R1 which consists of the Decade and Vernier controls. In practice, the value of R_2 can be adjusted by the CAL screwdriver adjust control to calibrate the output voltage with the panel dial markings.

3-6. BALANCED INPUT DETECTOR. Balanced input detector V11 functions as a symetrical balanced difference detector. Any voltage difference between grids is amplified and appears at the output plate as an error signal. Pin 2, the reference grid, is effectively at the zero point of the bridge (positive of the reference potential). Pin 7, the sampling grid, is at the other zero point on the opposite side of the bridge. Regulated plate supply voltage is taken from VR tube V4 and the cathodes are returned through resistor R23 to the -108 volts regulated by VR tube V6. The NULL screwdriver adjust control, R22, permits setting of the balanced input detector to zero difference between grids. Capacitor C8 bypasses degenerative ac components appearing across R22.

Output from plate 1 (pin 6) of V11 is applied across a coupling and voltage divider network consisting of glow discharge tubes V9 and V10 and resistors R13 and R15. These tubes couple plate potential to the grid of error amplifier V8, maintaining a constant voltage drop which permits the grid to follow the potential at the plate of V11. This constitutes an effective dc coupling which avoids any substantial loss of gain.

Note that the chopper-stabilized version of this power supply employs a 12AY7 in place of the 12AX7 for tube V11. Standard models include a ballast regulator RT1 to maintain a stable 6.3 volts ac across the heater of V11. The ballast is not required in the chopper-stabilized version and the RT1 socket is employed for the chopper-stabilizer unit with wiring changes shown in the schematic diagram.

3-7. ERROR AMPLIFIER. This stage employs tube V8 in high gain, low current operation. Output is direct-coupled to the control grids of the series tubes. Because the power supply has been designed to start at zero output, the output of the error amplifier must be driven to approximately -45 volts to cut off the series tubes. This is accomplished by returning the cathode of V11 to the -85 volts reference source so that sufficient voltage remains across the tube when the cutoff voltage is reached.

3-8. SERIES TUBES. Paralleled beam power pentodes V12 through V16 are employed as series elements, or variable conductances. Control grids are direct-coupled to the output of error amplifier V8. Any error voltage at the grids of the series tubes varies the conductance of these tubes. Thus an increase in the error voltage developed across the error amplifier plate load resistor, R3,will cause the conductance of the series tubes to decrease. Since the series tubes are connected in series between the positive supply and the positive output, the voltage drop across the tubes will increase, resulting in a decrease in the available output voltage. A decrease in the error voltage developed across R3 will cause a corresponding increase in the conductance of the tubes and an increase in the available output voltage.

3-9. CHOPPER STABILIZER. On units so equipped, the chopper stabilizer continuously corrects for zero offset in the balanced input detector, thereby eliminating output drift from this cause. Connected across the grids of balanced input detector V11, the chopper stabilizer continually samples the offset at grid 2 (pin 2), chops it to produce a square wave, amplifies, rectifies, and filters it, and applies the resulting correction signal to grid 1 (pin 7) to reduce the net offset to a vanishingly small value. Without chopper stabilization, this stage is subjected to drift to the extent that output voltage may change up to 0.1% or 50 millivolts for 8 hours. With chopper stabilization, stability becomes 0.05% or +2 millivolts which represents a ten-to-fifty times improvement at low voltages where divider action by the bridge makes zero offset in an unstabilized system the major source of drift. Because the chopper stabilizer adds gain of approximately 1000 to the regulator, and because it is unable to distinguish between offset due to drift and offset to varying line or load conditions, regulation is improved as shown in the Table of Specification, paragraph 1-3.

3-10. OUTPUT CIRCUITRY. The cathodes of series tubes V12 through V16, from which positive, regulated output voltage is obtained, are removed from the + binding post when H.V. switch S2 is set to the off (down) position. Setting S2 to the off position also shorts the + binding post to the - binding post to protect the power supply and the load from surges during standby operation.

Connected across the output terminals are resistor R24 and capacitor C10, the values of which are selected to adjust the characteristics of the feedback loop for stable operation. Also across the output is diode CR9, which protects the external load by presenting a low impedance path to any reverse voltage which may develop when the unit is turned off.

3-11. DECADE SYSTEM. The decade is inserted in series with resistor R42 to form one arm of the comparator. It consists of three switches, a potentiometer, several precision fixed resistors, and a corresponding amount of trimmer resistors. Each switch inserts the appropriate amount of resistors into the bridge circuit to provide the desired output voltage within the range indicated in the Table of Specifications, paragraph 1-3. The potentiometer is permanently connected in series with the decade switches and functions as a Vernier to provide an additional zero to one volt adjustment of the selected output voltage. The effective value of each fixed resistor can be adjusted to provide exact output voltage in accordance with the dial markings by means of associated trimmer resistors.

SECTION 4

MAINTENANCE

4-1. GENERAL. This section contains normal adjustment and periodic calibration procedures, general maintenance instructions, a trouble shooting table, and normal voltage and resistance measurements for the Precision Calibrated Power Supply. Reference should be made to the schematic diagrams in Section 5 of this instruction manual. Attention is called to the Warranty under which this instrument is sold, to be found opposite the Table of Contents page at the front of this instruction manual.

4-2. NULL ADJUSTMENT. The NULL screwdriver adjust control, located on the front panel, permits adjustment of the balanced input detector to null or zero, so that any remaining error is due principally to reference tube V7 (85A2). This adjustment is made as follows:

a. Remove the acorn nut covering the NULL screwdriver adjust control.

b. Place the power supply in operation at any voltage output. Load may remain connected.

c. Throw the meter switch to the OFF (middle) position and note the exact milliammeter indication.

d. Throw the meter switch to the NULL (down) position and adjust the NULL control to obtain the same indication on the milliammeter as was obtained with the switch in the OFF position.

e. Repeat steps c and d, above, several times.

f. Reset the Meter switch to the LOAD CURRENT (up) position.

4-3. NULL ADJUSTMENT FOR CHOPPER-STABILIZED UNITS. On units equipped with chopper stabilization, the NULL control should be set to the extreme clockwise position (maximum resistance), as viewed from the screwdriver end, for optimum operation. No attempt should be made to adjust the NULL control as described in paragraph 4-2 with the chopper stabilizer unit removed.

4-4. CALIBRATION OF OUTPUT VOLTAGE. This instrument is factory calibrated to deliver output voltages with a Decade dial accuracy of 0.1% or 25 millivolts, whichever is greater, and a Vernier accuracy of ±5%. Recalibration, should it become necessary after extended use, can be performed only with equipment capable of performing measurements which exceed the specified accuracy of the power supply. An extremely accurate resistance bridge is required. A highly accurate voltmeter capable of measuring 300 volts is also required. Note that the ratio of resistance to output voltage is 1000:1 over the entire output range.

In calibrating the standard version of this power supply (without chopper stabilization) the null adjustment procedure, paragraph 4-2, should be performed first. The next step is to connect an accurate voltmeter between the - and + binding posts, place the power supply in operation with the Decade adjusted for 300 volts output (Vernier at zero), remove the acorn nut covering the CAL screwdriver adjust control on the front panel, and adjust this control until the voltmeter indicates exactly 300 volts. The "hundreds" and "tens" Decade should then be set at zero, and the "units" Decade stepped from 10 to zero while observing the voltmeter indication at each step for output voltage accuracy. The "tens" Decade should then be stepped from 90 to zero while observing the voltmeter indication for accuracy at each step. Finally, the "hundreds" Decade should be set at 200, then at 100, while observing the voltmeter indication at each step. In the above procedure, note that the other two Decade are set at zero while the third is undergoing measurement. This is necessary to avoid accumulated error. If the observed voltmeter indications agree exactly with the dial markings throughout the Decade settings and upon adjustment of the CAL control, the power supply is correctly calibrated and requires no further adjustment. If one or more steps prove inaccurate, the following additional procedure should be performed:

a. Disconnect the power supply from the ac power source and remove the top cover.

b. Unsolder the lead wire connected to the fixed terminal of Vernier potentiometer R25. Do not disconnect the lead wire to the slider of the Vernier.

c. Connect one side of the resistance bridge to the lead wire removed from the Vernier in step b, above.

d. Connect the other side of the resistance bridge to the junction of resistor R143 and the contact of the "hundreds" Decade. This connection can also be made at pin 2 of tube V11, the balanced input detector.

e. Set the "hundreds" and "tens" Decade and the Vernier at zero. Set the "units" Decade to the one-volt position. Adjust trimmer R21 until the resistance bridge measures exactly 1000 ohms. Set the "units" Decade to the 2-volt position and adjust trimmer R22 to obtain exactly 2000 ohms. Adjust trimmers R23 and R24 to obtain exactly 3000 ohms and 4000 ohms for the 3-volt and 4-volt positions, respectively.

f. Perform resistance measurements for the 5-volt through 10-volt positions as a countercheck of the trimmer adjustments. If these measurements do not conform to the exact 1000: 1 ratio (5000 ohms, 6000 ohms, etc.) the trimmers should be rechecked by repeating step e, above.

g. Set the "units" Decade at zero, and set the "tens" Decade to the 10-volt position. Adjust trimmer R17, if necessary, to obtain exactly 10,000 ohms. Set the "tens" Decade to the 20-volt, 30-volt, and 40-volt positions and adjust trimmers R18, R19, and R20 to obtain exactly 20,000 ohms, 30,000 ohms, and 40,000 ohms, respectively.

h. Perform resistance measurements for the 50-volt through 90-volt positions as a counter-check of the trimmer adjustments. If the measurements do not conform to the exact 1000: 1 ratio (50,000 ohms, 60,000 ohms, etc.) the trimmers should be rechecked by repeating step g, above.

i. Set the "tens" Decade at zero, and set the "hundreds" Decade to the 100-volt position. Adjust trimmer R13 to obtain exactly 100,000 ohms. Set the "hundreds" Decade to the 200-volt position and adjust trimmer R14 to obtain exactly 200,000 ohms.

j. Disconnect the resistance bridge and replace the connection which was removed from the fixed terminal of Vernier potentiometer R25.

k. Connect the accurate voltmeter between the - and + binding posts. Place the power supply in operation with the Vernier set at zero and the Decade adjusted for 300 volts output.

l. Remove the acorn nut covering the CAL screwdriver adjust control on the front panel and adjust this control for a voltmeter indication of exactly 300 volts. This completes the output voltage calibration procedure.

4-5. CALIBRATION OF OUTPUT CURRENT MILLIAMMETER. Proceed as follows to calibrate the front panel output current milliammeter:

a. Connect a load which will draw approximately the full rated current of the calibrator at a given voltage. For example, with the controls of Model 2603 adjusted for 300 volts, a 1000-ohm resistor will draw 300 milliamperes. At 200 volts, a 600-ohm resistor will draw almost the full rating of 300 milliamperes.

b. Connect an external milliammeter of known accuracy in series with the load. Throw the Meter switch to the LOAD CURRENT position.

c. Place the power supply in operation and adjust trimmer R44 until the panel milliammeter indication agrees with the external milliammeter indication.

4-6. GENERAL FAULTS. If the output voltage drifts, chopper K1 or reference tube V7 (85A2) is most likely defective. Press a finger against the top of the chopper and feel for a steady vibration. If the vibration is absent or not steady, replace the chopper. Note the position of the internal light of the reference tube. If the light shifts from one location to another, replace the reference tube.

If, in chopper stabilized units, balanced input detector V11 is suspected of being faulty, perform the following procedure:

a. Place the power supply in operation with zero output, and connect a 100-millivolt meter across the + and - binding posts.

b. Rotate the NULL screwdriver adjust control to the extreme counterclockwise position and read the output in millivolts. Rotate the NULL control to the extreme clockwise position and read the output in millivolts. The difference between the two extremes should be less than 3 millivolts. If the difference is greater than 3 millivolts, replace tube V11.

c. Rotate the NULL control to the extreme counterclockwise position. The output must not exceed 2 millivolts above or below zero volts. If the output is greater than 2 millivolts from zero, replace tube V11.

d. Using a vacuum-tube voltmeter set to the lowest dc voltage scale, measure the voltage between pins 5 and 8 of octal socket J1. The voltage must be between zero and 0.750 volt. If the voltage is greater than 0.750 volt, replace tube V11.

When a malfunction appears to result from a faulty series tube, the following procedure is recommended:

a. Remove all series tubes but one.

b. Place the power supply in operation with 1/N of full load current at a low voltage, where N = number of series tubes in operation.

c. Check ripple and regulation.

d. Remove the remaining series tube, place another series tube in another socket, and repeat steps b and c, above. Repeat these steps for every other socket and tube, taking one at a time.

e. If one or more series circuits test faulty, repeat the test in each case with a tube known to be satisfactory. If the repeated test proves favorable it may be assumed that the previous tube is defective. Otherwise the associated circuit should be checked for faults.

4-7. PARTS REPLACEMENT. An electrical parts list accompanies the schematic diagrams in Section 5 of this instruction manual. In general, replacement parts are completely defined by the values and tolerances indicated in the parts list. The following components, however, require special attention:

a. Tubes V3 through V7. Replacement of any of these tubes will affect null balance, which should be readjusted in accordance with paragraph 4-2.

b. Tube V7. Replacement of reference tube V7 (85A2) will change the internal reference voltage and will require recalibration in accordance with paragraph 4-4. If the replacement tube does not yield approximately correct calibration, or proves unstable, a satisfactory tube will be furnished by the factory upon request.

c. Decades and Vernier. Defective components within the "hundreds", "tens", or "units" Decade or the Vernier potentiometer require exact replacements. No equivalents should be used.

4-8. CLEANING AND LUBRICATION. The power supply employs forced air cooling. After extended service, a considerable amount of dust will be deposited on most surfaces within the unit. About twice a year, remove the cover and cleanse all parts, particularly the fan blades, free of dust and grime. Lubricate the fan motor once or twice a year by injecting a few drops of light machine oil into the lubricating holes of the bearing straps.

4-9. TROUBLE SHOOTING. The following table is intended to serve as a brief guide in trouble shooting the power supply. It lists several possible symptoms of trouble which may develop, the most likely causes, and the remedies.

SYMPTOM	CAUSE	REMEDY
Unit dead when LINE switch thrown on.	LINE fuse F1 blown.	Replace fuse.
LINE fuse F1 blows repeatedly.	Rectifier tube V1 or V2 defective.	Replace defective rectifier tube.
	Rectifier CR5, CR6, or CR7 shorted.	Replace defective rectifier.
H.V. fuse F2 blows.	Short circuit load.	Check load.
	Overload, above rated output current.	Check load.
	With load connected, open circuit in Decade system.	Check Decade components and Vernier potentiometer for resistance.
No control of output, extremely high output voltage.	Series tube V12, V13, V14, V15, or V16 defective.	Replace defective series tube.
	Error amplifier V8 defective.	Replace tube.
	VR tube V5 or V6 defective.	Replace defective VR tube.
	Reference tube V7 defective.	Replace reference tube.
No control of output, low or zero output voltage.	Series tube V12, V13, V14, V15, or V16 defective.	Replace defective series tube.
	Diode CR9 shorted (across output terminals).	Replace diode.
	VR tube V3 or V4 defective.	Replace defective VR tube.
	Balanced input detector V11 defective.	Replace tube.
External voltmeter indications disagree with Decade and Vernier settings.		Recalibration necessary.
External voltmeter reads lower than Decade and Vernier settings but recalibration impossible or out of CAL control range.	Reference tube V7 shifted voltage.	Replace reference tube.
	VR tube V5 or V6 defective.	Replace defective VR tube.

SYMPTOM	CAUSE	REMEDY
Poor line regulation.	Defective tube.	Substitute tubes, except series tubes V12 through V16, one at a time until proper line regulation is restored. Replace defective tube.
Poor load regulation.	Poor load connections.	Check external load connections.
	Defective tube.	Substitute tubes one at a time until proper load regulation is restored. Replace defective tube.
NULL adjustment impossible.	H.V. fuse F2 blown.	Replace fuse.
	Defective tube.	Substitute tubes, except rectifier tube V1 and series tubes, one at a time until NULL adjustment is possible, Replace defective tube.
High ripple.	VR tube V5 or V6, or balanced input detector V11 defective.	Replace defective tube.
	Capacitor C1, C2, or C3 defective.	Replace defective capacitor.

4-10. VOLTAGE AND RESISTANCE MEASUREMENTS. Normal voltage and resistance measurements are given in the following tables.

NOTE

Voltage and resistance values may vary as much as 20% among production units without causing difficulties.

VOLTAGE MEASUREMENT

CONDITIONS

a. Primary input 115 volts, 50-60 cps, single-phase power.

b. LINE and H.V. switches set to on (up) position.

c. Decade set at 90 and Vernier set at 10.

d. No load connected to power supply.

e. Link connected between GND and - binding posts.

f. Measurements made from indicated tube pins to - binding post.

TUBE	PIN								
	1	2	3	4	5	6	7	8	9
V1	NC	520V	NC	380AC	NC	380AC	NC	520DC	-
V2	NC	520V	NC	380AC	NC	380AC	NC	520DC	-
V3	150	NC	NC	NC	150	NC	0	-	-
V4	105	NC	NC	NC	NC	NC	0	-	-
V5	0	-150	NC	-150	NC	NC	NC	-	-
V6	0	-105	NC	NC	NC	-105	NC	-	-
V7	0	-85	NC	NC	NC	0	NC	-	-
V8	-85	-85	6.3VAC	0	60	-42	-85	-	-
V11	105	0	2.5	0	0	40	0	.9	6.3VAC
V12 thru V16	NC	0	520	305	60	NC	0	100	-
chopper socket	0	0	105	NC	0	0	6.3VAC	0	-

RESISTANCE MEASUREMENT

CONDITIONS

a. LINE cord not connected to primary power source.

b. No load connected to power supply.

c. LINE and H.V. switches set to off (down) position.

d. Decade and Vernier set at 0.

e. Measurements made from indicated tube pins to - binding post.

TUBE	PIN								
	1	2	3	4	5	6	7	8	9
V1	NC	160K	NC	12	NC	12	NC	160K	-
V2	NC	160K	NC	12	NC	12	NC	160K	-
V3	170K	NC	NC	NC	170K	NC	0	-	-
V4	170K	NC	NC	NC	NC	NC	0	-	-
V5	0	145K	NC	145K	NC	NC	NC	-	-
V6	0	150K	NC	NC	NC	135K	NC	-	-
V7	0	120K	NC	NC	NC	∞	NC	-	-
V8	500K	120K	0	0	5meg	190K	120K	-	-
V11	170K	85K	300K	0	0	400K	1.2meg	300K	0
V12 thru V16	NC	∞	160K	3.5meg	5meg	NC	∞	85K	-
chopper socket	85K	0	160K	NC	1.2meg	0	0	0	-

MODELS 2601,2602,2603A/AK

CONTROL CONSTANT
1000 ohms-per-volt
115 volts, 50-60 cps input

REFERENCE SYMBOL	DESCRIPTION	TYPE OR PART NO.	MANUFACTURER
B1	Motor, shaded pole, 115 V, 50-60 CPS, 4 in. fan blade	DYAB-570-3	Barber-Colman
*C1-5	Capacitor, electrolytic, 80uf, 450 VDC, insul. sleeve	D15911	Sprague
C6	Capacitor, mica, 15uuf ±5%, 500 VDC	CM20B150J	Micamold
C7	Capacitor, mica, 220uuf ±5%, 500 VDC	CM20B221J	Micamold
*C8	Capacitor, electrolytic, 25uf, 25 VDC, insul. sleeve	KE-25/25	Frako
C9	Capacitor, mylar, 0.5uf +20% -10%, 400 VDC	Type 2110-BM	Chicago Cond.
*C10	Capacitor, electrolytic, 10uf, 400 VDC, insul. sleeve	TM-10/400	Pyramid
CORD	Line cord, 7' lg., #18 gauge, 3 cond., 3 prong plug	346-B-52	EMC
*CR1,2,5,6,7	Rectifier, selenium	8J1	Radio Receptor
*CR3,4	Rectifier, selenium (2602,2603)	8J1	Radio Receptor
*CR8	Diode, silicon	HC69	Solitron
*CR9	Rectifier, silicon	CER71	Solitron
*DS1,2	Lamp, 6.3 V., 0.25A.	44	G. E.
*DS3	Lamp, neon	NE-2	EMC
E1	Post, binding, red	29-3R	Grayhill
E2,3	Post, binding, black	29-3B	Grayhill
E4	Link, shorting	938-L	General Radio
E7	Link, shorting (TB1)	141-J	Cinch-Jones
*F1	Fuse, cartridge, 5 A.	3AG5	Sightmaster
*F2	Fuse, cartridge, 1/8 A. (2601)	3AG1/8	Sightmaster
*F2	Fuse, cartridge, 1/4 A. (2602)	3AG1/4	Sightmaster
*F2	Fuse, cartridge, 3/8 A. (2603)	3AG3/8	Sightmaster
J1	Socket, octal, 8 pin (RT1 or stabilizer unit connector)	9977	Cinch-Jones
M1	Milliammeter, 0-100 MADC ±2% full scale (2601)	Model 649/MA100	EMC
M1	Milliammeter, 0-200 MADC ±2% full scale (2602)	Model 649/MA200	EMC
M1	Milliammeter, 0-300 MADC ±2% full scale (2603)	Model 649/MA300	EMC
R1,2	Resistor, fixed, comp., 82K ±10%, 2W	HB-8231	Allen-Bradley
R3	Resistor, fixed, comp., 4.7 megohms ±10%, 1/2W	EB-4751	Allen-Bradley
R4	Resistor, fixed, comp., 1 megohm ±10%, 1/2W	EB-1051	Allen-Bradley
R5	Resistor, fixed, comp., 1000 ±10%, 2W	HB-1021	Allen-Bradley
R6	Resistor, fixed, WW, ceramic, 4000 ±5%, 10W	10KT4K	Sprague
R7	Resistor, fixed, comp., 3600 ±5%, 1W	GB-3625	Allen-Bradley
R8	Resistor, fixed, comp., 5600 ±5%, 1W	GB-5625	Allen-Bradley
R9	Resistor, fixed, comp., 330K ±10%, 1W	GB-3341	Allen-Bradley
R10	Resistor, fixed, comp., 390K ±10%, 1W	GB-3941	Allen-Bradley
R11	Resistor, fixed, comp., 5100 ±5%, 1W	GB-5125	Allen-Bradley
R12	Resistor, fixed, WW, vitreous enamel, 10K ±5%, 20W	Type 'Brown Devil'	Ohmite
R13,14	Resistor, fixed, comp., 100K ±10%, 1/2W	EB-1041	Allen-Bradley
R15	Resistor, fixed, comp., 330K ±10%, 1/2W	EB-3341	Allen-Bradley
*R18	Resistor, fixed, WW, 3000 ±1%, 1/2W	Type TX-178	Prec. Resistor
*R19	Resistor, fixed, WW, 76K ±1%, 3W	Type P3-W	Prec. Resistor
*R20,22	Resistor, variable, WW, 3000 ±5%, 2W, linear taper 1/4 in. dia. by 1/8 in. lg. slotted shaft, series 43	CM18923	Clarostat
R21	Resistor, fixed, comp., 220K ±10%, 1W	GB-2241	Allen-Bradley
R23	Resistor, fixed, comp., 150K ±10%, 1W	GB-1541	Allen-Bradley
R24	Resistor, fixed, WW, 1 ±5%, 1W	BW1	Int'l Resist.
R26,27,29,30	Resistor, fixed, comp., 47 ±10%, 1W	GB-4701	Allen-Bradley
R28,31	Resistor, fixed, comp., 470 ±10%, 1W	GB-4711	Allen-Bradley
R32,33,35,36	Same as R26, etc. (2602,2603)		
R34,37	Same as R28, etc. (2602,2603)		
R38,39	Same as R26, etc. (2603)		
R40	Same as R28, etc. (2603)		
*R41	Resistor, fixed, WW, 3000 ±1%, 1/2W	Type TX-178	Prec. Resistor
R42	Resistor, fixed, comp., 100 ±10%, 1/2W	EB-1011	Allen-Bradley
R43	Resistor, fixed, comp., 2200 ±10%, 1W	GB-2221	Allen-Bradley
R44	Rheostat, WW, 3000 ±20%, 1-1/2W	Type WC-808	Cont'l-Wirt
R45	Resistor, fixed, comp., 2.35 ±5%, 1W (Two (2) 4.7 ±5%, 1W in parallel) (2601)	GB-47G5	Allen-Bradley
R45	Resistor, fixed, WW, 1 ±5%, 1W (2602,2603)	BW1	Int'l Resist.
*RT1	Ballast tube (2601A,2602A,2603A)	Amp 3-4	Amperite
*S1	Switch, toggle, SPST	160-73	Carling
*S2	Switch, toggle, TPDT	HL233-73	Carling
*S3	Switch, toggle, DPDT	2GL53-73	Carling
T1	Transformer, filament & power	5001-E	EMC
TB1	Barrier strip, 3 terminal	3-141-Y	Cinch-Jones
TB2	Barrier strip, 3 terminal (rear termination only)	3-141-Y	Cinch-Jones
*V1	Electron tube	GZ 34/5AR4	Amperex
*V2	Electron tube same as V1 (2602,2603)		
*V3,5	Electron tube	OA2	RCA
*V4,6	Electron tube	OB2	RCA
*V7	Electron tube	85A2/0G3	Amperex
*V8	Electron tube	6AU6	RCA
*V9,10	Electron tube, neon	EM10	EMC

PARTS LIST

MODELS 2601,2602,2603A/AK
(continued)

REFERENCE SYMBOL	DESCRIPTION	TYPE OR PART NO.	MANUFACTURER
*V11	Electron tube (2601A,2602A,2603A)	12AX7	RCA
*V11	Electron tube (2601AK,2602AK,2603AK)	12AY7	G. E.
*V12,13	Electron tube	6L6GB	Sylvania
*V14,15	Electron tube same as V12,13 (2602,2603)		
*V16	Electron tube same as V12,13 (2603)		
XDS1	Holder assembly, pilot lamp, green faceted lens	100	Drake Mfg.
XDS2	Holder assembly, pilot lamp, red faceted lens	100	Drake Mfg.
XF1,2	Extractor post, fuse, miniature	342003	Littelfuse
XV1,12,13	Socket, 8 pin, octal (2601)	9977	Cinch-Jones
XV2	Same as XV1 (2602,2603)		
XV3-XV8	Socket, 7 pin, miniature	53P24022	Cinch-Jones
XV11	Socket, 9 pin, noval	14502	Cinch-Jones
XV14,15	Same as XV1, etc. (2602,2603)		
XV16	Same as XV1, etc. (2603)		

DECADE SYSTEM, 337-C-11

*R1	Resistor, fixed, WW, 100K +0.0% -0.1%, 1-1/4W	Type 218RL	Consolidated
*R2	Resistor, fixed, WW, 200K +0.0% -0.1%, 1-1/4W	Type 218RL	Resistance
*R5	Resistor, fixed, WW, 10K +0.0% -0.1%, 7/8W	Type P17RL	Company
*R6	Resistor, fixed, WW, 20K +0.0% -0.1%, 7/8W	Type P17RL	
*R7	Resistor, fixed, WW, 30K +0.0% -0.1%, 7/8W	Type P17RL	
*R8	Resistor, fixed, WW, 40K +0.0% -0.1%, 7/8W	Type P17RL	
*R9	Resistor, fixed, WW, 1000 +0.0% -0.1%, 1/2W	Type 215RL	
*R10	Resistor, fixed, WW, 2000 +0.0% -0.1%, 1/2W	Type 215RL	
*R11	Resistor, fixed, WW, 3000 +0.0% -0.1%, 1/2W	Type 215RL	
*R12	Resistor, fixed, WW, 4000 +0.0% -0.1%, 1/2W	Type 215RL	
R13	Resistor, variable, WW, 100 ±10%, 0.25W	Model 200	Bourns
R14	Resistor, variable, WW, 200 ±10%, 0.25W	Model 200	Bourns
R17	Resistor, variable, WW, 10 ±10%, 0.25W	Model 200	Bourns
R18	Resistor, variable, WW, 20 ±10%, 0.25W	Model 200	Bourns
R19,20	Resistor, variable, WW, 50 ±10%, 0.25W	Model 200	Bourns
R21	Rheostat, WW, 2 ±20%, 1-1/2W	Type WC-808	Cont'l-Wirt
R22	Rheostat, WW, 2 ±20%, 1-1/2W	Type WC-808	Cont'l-Wirt
R23	Rheostat, WW, 5 ±20%, 1-1/2W	Type WC-808	Cont'l-Wirt
R24	Rheostat, WW, 5 ±20%, 1-1/2W	Type WC-808	Cont'l-Wirt
*R25	Resistor, variable, WW, 1000 ±2%, 8W, linear taper	336-A-58	EMC
*S1,2,3	Switch, rotary	336-A-11	EMC

CHOPPER STABILIZER UNIT, 336-A-32

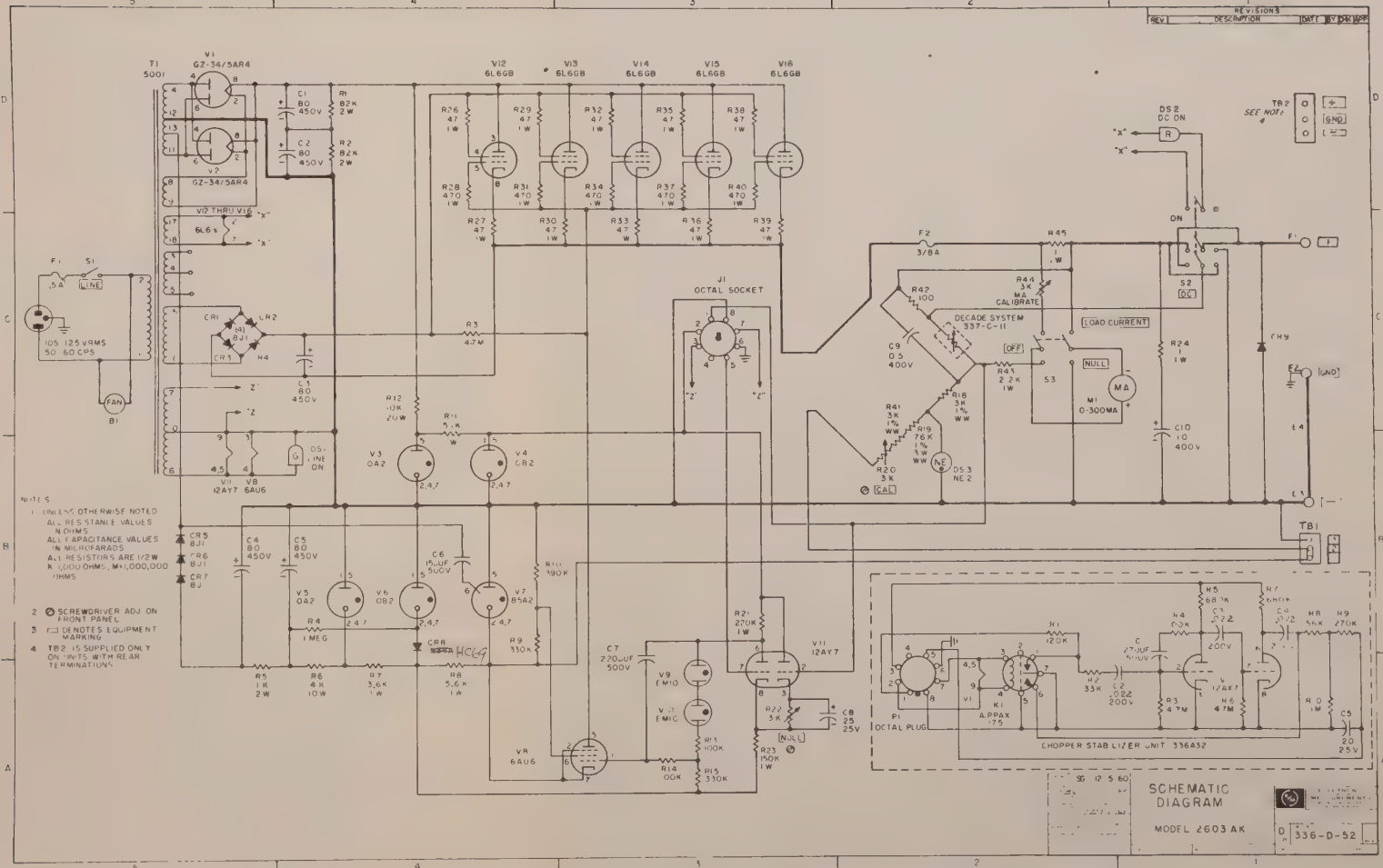
C1	Capacitor, mica, 27uuf ±5%, 500 VDC	CM19B270J	Arco
C2,3,4	Capacitor, mylar, 0.022uf ±10%, 200 VDC	107-0.022/200	Pyramid
*C5	Capacitor, tantalum, etched foil, non-polarized, 20uf ±20%, 25VDC	TAE20-25SDLK-NP	Int'l Elect's
*K1	Chopper, SPDT, 6.3V, 60 CPS	Model 175	Airpax
P1	Plug, octal	86-CP8	Amphenol
R1	Resistor, fixed, comp., 120K ±10%, 1/2W	EB-1241	Allen-Bradley
R2	Resistor, fixed, comp., 33K ±10%, 1/2W	EB-3331	Allen-Bradley
R3,6	Resistor, fixed, comp., 4.7 megohms ±10%, 1/2W	EB-4751	Allen-Bradley
R4	Resistor, fixed, comp., 100K ±10%, 1/2W	EB-1041	Allen-Bradley
R5,7	Resistor, fixed, comp., 680K ±10%, 1/2W	EB-6841	Allen-Bradley
R8	Resistor, fixed, comp., 56K ±10%, 1/2W	EB-5631	Allen-Bradley
R9	Resistor, fixed, comp., 270K ±10%, 1/2W	EB-2741	Allen-Bradley
R10	Resistor, fixed, comp., 1 megohm ±10%, 1/2W	EB-1051	Allen-Bradley
*V1	Electron tube	12AX7	RCA

PARTS LIST ADDENDUM, 220 volts, 50-60 CPS input version

B1	Motor, shaded pole, constant speed, 220V., 50-60 CPS, 4 in. fan blade	1075-3174	Howard
*DS1,2	Lamp, 6.3V., 0.25A	44	G. E.
*F1	Fuse, cartridge, 3A.	3AG3	Sightmaster
*S1	Same as for 115 volt input.		
T1	Transformer, filament and power	5182	EMC

NOTES:

1. *ASTERISKED PARTS are recommended spares in quantity one per reference symbol, except fuses, which are three per reference symbol.
2. WHEN MAKING REPLACEMENTS: Part numbers are indicative of stock employed at the time of compilation of this list. Unless otherwise noted, and except for Electronic Measurements (E/M) numbers, "or equal" parts may be used for replacement. Electronic Measurements reserves the right to replace a part with an "or equal" part.
3. WHEN ORDERING PARTS FROM E/M: Include model and serial numbers of the instrument. Note carefully and include the letter suffix of any transformer number. In case of a discrepancy between a parts list number and the number actually printed on the part, employ the latter.
4. RECOMMENDED SPARES. When electrolytic capacitors are to be stored as spares for a year or more, request Technical Note 32.


REVISIONS
REV DESCRIPTION DATE BY CK'D APP'D
T1 5001
V1 GZ-34/5AR4
V2 GZ-34/5AR4
V12 THRU V16 6L6
V12 6L6GB
V13 6L6GB
V14 6L6GB
V15 6L6GB
V16 6L6GB
C1 80 450V
C2 80 450V
R1 82K 2W
R2 82K 2W
R26 47 1W
R29 47 1W
R32 47 1W
R35 47 1W
R38 47 1W
R28 470 1W
R31 470 1W
R34 470 1W
R37 470 1W
R40 470 1W
R27 47 1W
R30 47 1W
R33 47 1W
R36 47 1W
R39 47 1W
F1 .5A
S1 LINE
105 125 VRMS 50 60 CPS
B1 FAN
CR1 CR2 CR3 CR4 (4) 8J1
C3 80 450V
R3 4.7M
J1 OCTAL SOCKET
R12 10K 20W
R11 5.1K W
V3 0A2
V4 0B2
V8 12AY7 6AU6
DS1 LINE ON
CR5 8J1
CR6 8J1
CR7 8J1
C4 80 450V
C5 80 450V
C6 15UUF 500V
R10 190K
V5 0A2
V6 0B2
V7 85A2
R4 1 MEG
CR8 HC64
R9 330K
R5 1K 2W
R6 4K 10W
R7 3.6K 1W
R8 5.6K 1W
C7 220UUF 500V
V9 EM80
V10 EM80
R13 100K
R14 100K
R15 330K
V11 12AY7
R21 270K 1W
R22 3K
R23 190K 1W
C8 25 25V
V8 6AU6
NOTES
1 UNLESS OTHERWISE NOTED ALL RESISTANCE VALUES IN OHMS. ALL CAPACITANCE VALUES IN MICROFARADS. ALL RESISTORS ARE 1/2W. K=1,000 OHMS, M=1,000,000 OHMS.
2 SCREWDRIVER ADJ ON FRONT PANEL
3 DENOTES EQUIPMENT MARKING
4 TB2 IS SUPPLIED ONLY ON UNITS WITH REAR TERMINATIONS
DS2 DC ON
TB2 SEE NOTE 4
GND
F2 3/8A
R45 1 1W
R44 3K MA CALIBRATE
S2 DC
R42 100
DECADE SYSTEM 337-C-11
LOAD CURRENT
C9 0.5 400V
OFF
NULL
R43 2.2K 1W
S3
M1 0-300MA
R24 1 1W
CR4
C10 10 400V
R41 3K 1% WW
R19 76K 1% 3W WW
R18 3K 1% WW
R20 5K
DS3 NE2
CAL
E2 GND
E4
E3
TB1
P1 OCTAL PLUG
R1 120K
C1 .022 200V
R2 33K
C2 .022 200V
R3 4.7M
R4 .05K
R5 68.1K
R6 4.7M
R7 6.81K
R8 5.6K
R9 470K
R10 1M
C5 20 25V
CHOPPER STABILIZER UNIT 336A32
SCHEMATIC DIAGRAM
MODEL 2603 AK
D 336-D-52

Warranty

Electronic Measurements instruments are guaranteed to be free from defects in material and workmanship for one year from the date of purchase (except for tubes, fuses and batteries). Our liability under this warranty is limited to repairs and adjustments or replacements of defective parts or instruments when the fault is a direct result of defective materials or workmanship in the manufacture of the apparatus. This warranty covers service for the first year, except for transportation to and from the factory. If any fault develops in the equipment, the following steps should be taken:

1. Notify ELECTRONIC MEASUREMENTS CO., INC. Give full particulars of the difficulty and include the serial number of the instrument in question. On receipt of this information, we will give you service information or shipping instructions.
2. On receipt of shipping instructions, forward the appartus to us, prepaid, and we will make repairs and adjustments immediately at the factory.
3. If the fault has been caused by misuse, or abnormal conditions of operation, as disclosed by our examination, repairs will be billed at cost. In this case, an estimate of the cost will be submitted before work is started.

ELECTRICAL STANDARDS

All company primary standards are either certified directly or are traceable to certification by the National Bureau of Standards.

CLAIM FOR DAMAGE IN SHIPMENT

This instrument received comprehensive visual and electrical inspections before shipment. Immediately upon receipt from the carrier, and before operation, this instrument should be inspected visually for damage caused in shipment. If such inspection reveals internal or external damage in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. When referring to this instrument, always include the model and serial numbers.